Marine Physical Laboratory

Acoustic Emissions of Bubble Clouds in Salt Water

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Summary

Experiments were performed to investigate the sound from an axi-symmetric, conical bubble plume formed by a continuous, vertical water jet as it penetrates the surface of a pool of water. The volume fluxes of the air and water entering the pool were carefully controlled and monitored during the experiments and a hydrophone detected the acoustic pressure field adjacent to the plume at frequencies between 100 Hz and 1 kHz. Up to five well-defined, non-uniformly spaced peaks were observed in the pressure spectrum.

These peaks are attributed to coherent, collective oscillations of the bubbles within the plume, implying that the biphasic bubbly medium acts as a continuum, forming a resonant, conical cavity beneath the jet. All the eigenfrequencies were found to exhibit inverse-fractional power-law scalings of the same form: fm µ uj-1/2q-1/4, where fm is the frequency of the mth spectral peak, uj is the jet velocity, q is the air entrainment ratio, that is, the ratio of the air-to-water volume fluxes in the jet, and the unspecified constant shows a non-linear dependence on m. A two-component, theoretical model has been developed for the eigenfrequencies of the plume.

From a fluid-dynamics argument based on the conservation of momentum flux in the two-phase flow, the speed of sound within the

bubbly medium is shown to increase as the square-root of depth in the plume. This is incorporated into an acoustic analysis in which the wave equation is solved analytically, taking account of the cone-like geometry of the bubble plume cavity, including the near-rigid boundary condition at the penetration depth, where the bubbly region ends abruptly. The resultant expression for the frequencies of the lowest-order longitudinal modes of the bubble-plume cavity exhibits the inverse-fractional power-law scalings observed in the experiments. It is evident from the theory that the square-root sound speed profile within the plume is the origin of the inverse relationship between the eigen-frequencies and the square-root of the jet velocity, as observed at the hydrophone external to the plume.

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